

NASA

*N-02*  
*384 498*

# MEMORANDUM

FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED

OPERATION OF JET TRANSPORTS

By Stanley P. Butchart, Jack Fischel, Robert A. Tremant,  
and Glenn H. Robinson

High-Speed Flight Station  
Edwards, Calif.

NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION

WASHINGTON

April 1959



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

---

MEMORANDUM 3-2-59H

---

FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED

OPERATION OF JET TRANSPORTS

By Stanley P. Butchart, Jack Fischel, Robert A. Tremant,  
and Glenn H. Robinson

SUMMARY

A flight investigation was made to assess the potential operational problems of jet transports in the transonic cruise range. In this study a large multiengine jet airplane having geometric characteristics fairly representative of the jet transport was used; however, in order to ensure general applicability of the results, the aerodynamic characteristics of the test airplane were varied to simulate a variety of jet-transport airplanes.

Some of the specific areas investigated include: (1) an overall evaluation of longitudinal stability and control characteristics at transonic speeds, with an assessment of pitch-up characteristics, (2) the effect of buffeting on airplane operational speeds and maneuvering, (3) the desirable lateral-directional damping characteristics, (4) the desirable lateral-control characteristics, (5) an assessment of over-speed and speed-spread requirements, including the upset maneuver, and (6) an assessment of techniques and airplane characteristics for rapid descent and slow-down.

The results presented include pilots' evaluation of the various problem areas and specific recommendations for possible improvement of jet-transport operations in the cruising speed range.

INTRODUCTION

In an assessment of problems other than those encountered in the take-off and landing area which could possibly affect operations of jet transports, the region determined as most likely to be critical was the transonic region because of the changes in aerodynamic phenomena which could affect the safety or comfort of flight. Although the effects occurring in this speed range have been extensively explored by research

and military aircraft and are well known, some question exists regarding the importance of these effects on civilian passenger-carrying airplanes.

For the purpose of investigating the overall significance of these effects as they might affect airline operations, a large multijet airplane, basically similar to the jet transports currently being produced, was utilized to evaluate the specific problem areas.

#### SYMBOLS

$a_n$	normal acceleration, g units
$b$	wing span, ft
$C_m$	airplane pitching-moment coefficient
$C_N$	airplane normal-force coefficient
$F_e$	longitudinal control force, lb
$M$	Mach number
$M_1$	Mach number at initiation of maneuver
$p$	rate of roll, radians/sec
$p_b/2V$	wing-tip helix angle or lateral control effectiveness parameter, radians
$S$	wing area, sq ft
$T$	engine thrust, lb
$T_{1/2}$	time for lateral-directional oscillation to damp to half amplitude, sec
$T_2$	time for lateral-directional oscillation to double amplitude, sec
$T_{\phi=30^\circ}$	time to change bank angle $30^\circ$ , sec
$V$	true velocity, ft/sec
$V_i$	calibrated indicated airspeed, knots

$W$	airplane weight, lb
$\alpha_i$	indicated angle of attack, deg
$\delta_e$	elevator deflection, deg

## PROBLEM AREAS IN JET-TRANSPORT OPERATION

The problem areas to be considered in the present investigation of jet transports are as follows:

- (1) Overall longitudinal stability and control characteristics at transonic speeds
- (2) Buffeting
- (3) Desirable lateral-directional damping characteristics
- (4) Desirable lateral-control characteristics
- (5) Overspeed and speed-spread requirements
- (6) Techniques and airplane characteristics for emergency descent and slow-down.

For the purpose of this study, a large multijet airplane basically similar to jet transports now in production was tested in flight. This airplane configuration had a  $35^\circ$  sweptback wing of aspect ratio 7.1. A two-view drawing of the airplane is shown in figure 1.

## RESULTS AND DISCUSSION

### Trim Characteristics

Inasmuch as the economics of jet-transport operation will dictate that airplanes of this type cruise in the transonic speed range, they will be flying in a region where the usual unstable longitudinal trim variations will be encountered. A question exists as to whether this is a potentially dangerous area in which to operate. Figure 2 shows typical trim variations of elevator force and position with Mach number for two altitudes; stabilizer setting was held constant. The solid lines represent operation in level flight (normal acceleration of 1 g) and the dashed lines represent trim level for a normal acceleration

of 1.5g. When the airplane accelerated longitudinally in level flight through the speed range to the unstable region of the trim curve, the force reversal was mild and occurred at such a rate that the airplane could be trimmed at all times. For example, at an altitude of 25,000 feet, approximately 75 seconds was required for a Mach number increase from 0.75 to 0.85, and at 35,000 feet the time required for a similar increment in speed was approximately doubled. In decelerating through this "tuck" or transonic region, the force change from an unstable trend to a stable trend occurred at a more rapid rate, depending on the technique used for slow-down, but was still considered slow enough to enable the pilot to maintain a 1g trim condition at all times. For example, when the airplane decelerated with throttles in the idle position and speed brakes extended, approximately 35 seconds was required for a Mach number decrease of 0.1 at 25,000 feet. Should a pilot decelerate while holding the stick force constant or while increasing the stick force to obtain a higher normal acceleration, it is possible to obtain higher levels of normal acceleration, perhaps approaching structural limits, as a result of control reversal in the transonic region. This possibility is apparent from the trends and levels of control force and position for trimmed flight at 1g and 1.5g shown in figure 2. The trend of the power-off trim variations through the speed range was similar to that shown for the power-on condition; however, the levels of force and elevator position required were somewhat higher for the power-off condition. When the airplane decelerated (decreasing M) with engines idle and speed brakes open, the trim variations were similar in trend and magnitude to those shown for the power-on acceleration (M increasing), so that the individual effects on trim associated with these variables were indicated to be compensating. It is believed that if this transonic region were traversed appreciably faster with the force variations shown, or if the changes in control force were approximately doubled with the existing rate of Mach number change specified, the trim variations would be very objectionable. From consideration of these factors, it appears that a force variation with speed of 40 or 50 pounds should be the maximum allowable.

Although the trim variations recorded over the transonic speed range appear more acute for the higher altitude, this difference was not readily apparent to the pilot. The variation with Mach number of elevator position and force required for trimmed flight at a normal acceleration of 1g in the transonic region was essentially unaffected by changes in center-of-gravity position. Operation under instrument flight conditions in the transonic region provided no additional handling difficulties, inasmuch as operation under visual flight conditions required the use of instruments to control the flight path at high altitude.

Cruising in the unstable portion of the transonic region with autopilot off requires constant pilot attention, since small disturbances of equilibrium conditions have a divergent effect on speed and altitude. Performing a change in heading in the unstable trim region provides added difficulty for the pilot in maintaining altitude control because of the forward stick displacement required as the speed tends to decrease.

From the pilot's viewpoint, it would be desirable to have the unstable force variations masked in order to provide stable trim force variations throughout the speed range.

### Pitch-Up Characteristics

In maneuvers to normal acceleration in excess of  $1g$  with swept-wing airplanes, pitch-up has been encountered which was quite severe for the smaller aircraft and often bordered on being dangerous. Data obtained on the test airplane during an accelerated maneuver are presented in figure 3, together with comparable data obtained with the B-47 airplane. Time histories of similar slow-rate wind-up turns are shown as variations of stick force, elevator angle, normal acceleration, and angle of attack for each aircraft. Also shown are corresponding variations of airplane pitching moment with angle of attack. Despite the decrease in stability with increase in angle of attack for the test airplane, as exhibited by the decrease in slope of the pitching-moment curve, the rates of rotation were so low that the pilot generally was not cognizant of this pitch-up effect. This mild effect can be attributed to the gradual change in slope of the pitching-moment curve and the large aircraft inertia. The airplane was controllable at all times. However, if the change in slope of the pitching-moment curve is more radical and exhibits an unstable trend, as shown for the B-47, the pitch-up is very apparent and can be potentially dangerous at altitudes where design limits can be exceeded in the overshoot of normal acceleration. For this degree of instability with the large aircraft, recovery from pitch-up is slow and generally requires appreciable pilot effort. For both airplanes, buffet barely preceded the pitch-up and could serve as a warning for slow rates of entry. If the control system is such that the stick-force gradient has an abrupt decrease with increased normal acceleration, an apparent pitch-up, which can be potentially dangerous, is evident to the pilot.

### Buffeting Characteristics

When Mach number increased in level flight at altitudes above approximately 25,000 feet, or when maneuvers were performed to levels

of normal acceleration in excess of 1 g, buffeting was encountered. Figure 4 shows the variation of normal-force coefficient with Mach number for the onset of buffeting for the test airplane. The buffeting is first perceptible to the pilot through the control column and is similar to rough-air turbulence; the intensity rise is quite gradual with increase in speed or normal acceleration. On this airplane the severity of buffeting did not appreciably limit aircraft maneuvering up to the maximum of 2g tested. However, consideration of passenger comfort may dictate that the aircraft be operated sufficiently below this boundary to permit normal maneuvering without encountering buffeting. For example, for an airplane with a wing loading of 75 lb/sq ft operating at an altitude of 35,000 feet, for which the lower dashed line in this figure shows the variation of level flight (1 g) normal-force coefficient with Mach number, a normal operating Mach number 0.03 below that for level-flight buffeting would provide a normal-acceleration maneuvering range of 0.5g prior to encounter of buffeting at essentially constant speed.

Although little difference could be detected between the buffeting encountered at high speed and that produced by high-altitude turbulence, it is believed that buffeting would serve as a warning, in any case, for the pilot to slow down.

For an airplane that was performance-limited in level flight to operation slightly above or in the buffet boundary, an accelerated longitudinal maneuver would cause a decrease in speed so that the variation of  $C_N$  with  $M$  would parallel the buffet boundary with little or no increase in buffet severity. For an airplane that was not performance-limited and which could operate at speeds well into the buffet boundary, an accelerated maneuver could produce sizable increases in severity of buffeting.

#### Lateral-Directional Damping Characteristics

In order to evaluate the degree of lateral-directional damping desired for high-altitude cruise, various lateral-directional dynamic characteristics were obtained on the test airplane by using a yaw damper. The dynamic characteristics shown in figure 5 were obtained by varying the yaw-damper gain setting. This figure shows the variation of time to damp to half amplitude or the time to double amplitude of the lateral-directional oscillation with Mach number. Data are presented for three damper conditions: damper on, off, and reversed. Reversed damping was evaluated to investigate handling characteristics with materially less damping than that produced by the basic airframe. At Mach numbers below about 0.84 the damping of the basic airplane with damper off was satisfactory in smooth air in straight and level flight



but was considered marginal for smooth-air maneuvering, because of the residual induced oscillations. During high-altitude flight in turbulence, the damping became unsatisfactory. In this speed range the damping provided with damper on was particularly beneficial at high altitude and in rough air and would provide a margin of comfort for passenger-carrying aircraft. At near maximum speeds it was sometimes difficult to appreciate any additional damping provided by the yaw damper because of the improved aerodynamic damping. The level of damping provided by the reversed damper was entirely unsatisfactory and would constitute an emergency condition from structural considerations, even though the pilot could control the aircraft. From the viewpoint of airplane controllability and passenger comfort, it is felt that lateral-directional damping should be sufficient to damp any oscillation to half amplitude within 3 or 4 seconds.

#### Evaluation of Desirable Lateral-Control Characteristics

Lateral-control requirements for the high-altitude cruise condition appear to be much less stringent than for the low-speed landing and take-off condition that is discussed in reference 1. Figure 6 shows the results of rudder-fixed aileron rolls where time to bank  $30^\circ$ , maximum helix angle, and maximum roll rate are plotted against Mach number. The data are presented in these three forms for comparison and discussion purposes. The solid lines show the lateral-control power produced by full deflection of inboard ailerons alone, and the dashed lines represent the lateral-control power produced by inboard ailerons and all spoiler controls. The control levels produced by ailerons and either inboard or outboard spoilers were evaluated and provided intermediate control levels, as anticipated. The apparent decay in performance above a Mach number of approximately 0.8 is a result of spoiler blow-down with increasing dynamic pressure.

The helix angle of 0.02 shown for ailerons alone appears to be low when compared with the Air Force requirement of 0.07 for transport aircraft. Testing has shown that for small course corrections or heading changes requiring up to  $30^\circ$  bank angle, ailerons alone gave a comfortable rate of roll. It is believed that a roll rate of not more than 0.2 or 0.3 radian per second should be adequate for normal operations.

For this particular airplane configuration the absence of spoiler buffeting, when ailerons alone are used for lateral maneuvering, is an added attraction for pilots and passengers alike. With an aim at keeping as much lateral control as possible for collision avoidance, some thought might be given to the use of a differential control where the spoilers would be employed after approximately 60 to 70 percent of the control-wheel "throw."

### Assessment of Overspeed Capabilities

As the aircraft designer labors to make his airplane go ever faster, the existing problems of overspeed and speed control become still greater because of the possibility of exceeding design limits, even in level flight. Figure 7 shows the potential of the airplane in exceeding the dynamic-pressure design limits in case climb power is retained after level off at altitude. The solid lines represent the data from tests at two altitudes for a thrust-weight ratio of 0.23. At 12,000 feet and a climb speed of 280 knots, approximately 75 seconds was required before an arbitrary placard speed of 350 knots was reached. At 25,000 feet a full 2 minutes elapsed for essentially the same increase in speed. The dashed lines represent data for the same airplane using engines having thrust-weight ratios of 0.29, and even greater thrust potentials can be imagined. The seriousness of the problem is somewhat reduced at higher altitudes, where the airplane has Mach number limitations and the pilot has a certain amount of buffet warning. At lower altitudes where the transport has dynamic pressure limitations, the pilot has only his airspeed instrument to warn him of approaching limits. This instrument could be neglected during instrument-flight conditions involving increased cockpit activity and attention to other details. The addition of a horn, bell, or warning light, or a combination, appears to be the best solution to the problem.

### Upset-Maneuver Evaluation

Closely associated with the level-flight overspeed problem is the possibility of the airplane exceeding design limits during a so-called "upset" maneuver resulting in a dive. In order to provide information leading to speed-spread requirements, an evaluation of various upset maneuvers was made. In general, the upsets were initiated from cruise in level flight by pilot-induced control movement. Figure 8 shows the results of some of these tests performed at two altitudes for various dive angles. At 25,000 feet, a placard speed of 365 knots was used, and the upset maneuvers were started 25 to 45 knots below this placard speed. The time required to reach maximum speed is shown as the end point of each maneuver; however, the recovery technique was started earlier as shown by the marks indicating throttle to idle or speed brakes open. For the 35,000-foot condition a Mach number of 0.9 was used for the placard speed and starting Mach numbers as high as 0.875 were used. Dive angles varied from  $4^{\circ}$  to  $16^{\circ}$ .

It was felt that placing the airplane in a dive by elevator control was rather unrealistic and a more severe requirement might result when the upset maneuver was executed by a runaway stabilizer trim motor. In these tests the copilot initiated the upset by use of the stabilizer trim switch, and the pilot's task after recognizing the

upset was first to halt the runaway condition and then to recover. An example of this type of maneuver is shown for an altitude of 35,000 feet (fig. 8) at a dive angle of  $4^\circ$  which resulted in a speed increase of approximately 10 knots. This method of testing pointed up the desirability of having a positive nose-up trim change with application of speed brakes, which materially helped in recovery where elevator stick force was high as a result of runaway trim. The pilot was usually aware of the upset in 2 to 3 seconds, and recovery action was taken immediately, using not over 1.5g. The speed brakes were most effective in controlling speed, as can be seen by the short time interval between their application and the maximum speed attained.

A few more comments pertinent to the upset condition and speed-spread requirements are considered necessary. It is difficult to specify exact speed-spread requirements because of the important effect of the drag rise in limiting aircraft maximum speeds. An example of this can be seen in figure 8 for an altitude of 35,000 feet, where an upset initiated at  $M \approx 0.875$  with an  $11^\circ$  dive angle produced a smaller speed increment than an upset initiated from  $M \approx 0.805$  with a  $12^\circ$  dive angle. Thus, an airplane having its limiting or design speed barely in the drag-rise region might be unduly penalized by a speed-spread requirement based on a given upset maneuver compared with another airplane having its limiting or design speed well into the drag-rise region.

#### Slow-Down and Descent Evaluation

The inability to slow down a fast-moving transport becomes greater as speed and weight are increased. The need for a slow-down capability may arise when encountering heavy turbulence or in an aircraft emergency. Figure 9 shows the time required to slow down to the landing-gear placard speed from cruise conditions at two altitudes. Various techniques were used such as throttle "chop" to idle; throttle chop T plus opening of speed brakes B; and finally throttle chop T, speed brakes B, and a 1.5g turn or pull-up W. For the 35,000-foot altitude the time required was cut in half when speed brakes were added to the throttle chop. This time was again cut in half when a 1.5g pull-up was used with the throttle chop and speed brakes. Obviously, this last method cannot be used where strict altitude limits are needed but does illustrate the potential available if a slight pull-up could be used. In the test cases approximately 1,200 feet altitude was gained during the maneuver.

The penalties associated with providing adequate drag by means of speed brakes have caused a general use of the landing gear as a drag device. Probably the greatest single improvement for slow-down capabilities, therefore, would be in the designing of the landing gear for

operation at speeds at or near cruise conditions. A landing gear that could be lowered at all operational speeds should be available at all times when operating above 30,000 feet. This requirement becomes of prime importance when emergency descent from altitude is considered. Figure 10 illustrates this point by showing the descent capabilities of the test airplane utilizing two different techniques. Descent performed with the normal technique, represented by the solid line, utilized a throttle chop T (at time zero) and extension of landing gear G. The emergency technique, represented by the dashed line, was performed with a throttle chop, extension of landing gear G, and opening of speed brakes B. Also shown is a curve representing the time for personnel unconsciousness at a given altitude upon complete loss of cabin pressurization. It can be seen that when the airplane cruises at an initial Mach number  $M_1 = 0.88$  at an altitude of 35,000 feet, more than 30 seconds of throttle at idle were necessary before gear-down speed was reached. When this time is compared with the 30 seconds shown for loss of consciousness at this altitude, any time saved in using all drag devices is of great importance. Had it been possible to lower the landing gear at cruise speed, the descent curve could possibly remain within consciousness levels. For the emergency descent initiated from an altitude of 40,000 feet, maximum speed attainable was below gear placard speed and consequently the gear could be lowered immediately.

The emergency descent technique provided rates of descent up to about 9,000 feet per minute, which is a marked improvement over the normal technique; however, the buffeting, noise, and objectionable airplane attitude associated with this technique would obviously limit its use to emergencies only.

#### Supersonic Pass Evaluation

Some question has existed regarding the effects on a large jet transport resulting from the passing of another aircraft in close proximity at supersonic speeds. An evaluation of this potential problem area was performed with the test airplane, which was flown at an altitude of 35,000 feet and a Mach number of 0.8. An overtaking fighter airplane was used to generate the supersonic flow field. Data were obtained from a pass of the supersonic airplane flying 500 feet directly below the test airplane at  $M = 1.2$  and then from a lateral pass with 500 feet of separation at  $M = 1.8$ . In neither instance did the test airplane experience any measurable changes in angle of attack or sideslip. For the underneath pass, the normal-acceleration excursion was  $\pm 0.05g$ . For the lateral pass, the vertical-tail load was less than 1 percent of the design limit load. In both cases the pilot could barely detect the passing shock wave.

## CONCLUDING REMARKS

The following conclusions are based on a flight evaluation of the problems that could affect operation of jet transports in the transonic region:

1. Unstable control characteristics encountered in the transonic speed range are controllable if the magnitude of force reversal and rate of speed change are moderate. From the pilot's viewpoint, it would be highly desirable to provide some automatic device to give stable trim control-force variations in the transonic region; however, with such automatic device inoperative, the basic airplane force variation with speed should be no greater than about 40 or 50 pounds.

2. A normal operating Mach number approximately 0.03 below that for level-flight buffeting is recommended to provide an adequate maneuvering range.

3. A slight reduction in longitudinal stability can be tolerated because of the slow pitch rates involved.

4. From the viewpoint of airplane controllability and passenger comfort, it is believed that lateral-directional damping should be sufficient to damp any oscillation to half amplitude within 3 or 4 seconds.

5. A roll rate of 0.2 to 0.3 radian per second was found to be adequate for normal high-speed maneuvering.

6. Inasmuch as a potential exists for exceeding maximum-speed design limits, especially at lower altitudes where warning provided by such phenomena as buffeting is not present, it is recommended that a horn or other device be provided as a warning to the pilot.

7. An upset maneuver induced by stabilizer input, which was judged to be a realistic evaluation maneuver, provided a speed increment of the order of 10 to 15 knots, and recovery from this maneuver was readily effected.

8. In order to perform optimum slow down or descent such as might be required for emergency conditions, extension of the landing gear to provide drag at all operational speeds above 30,000 feet is recommended.

High-Speed Flight Station,  
National Aeronautics and Space Administration,  
Edwards, Calif., November 5, 1958.

## REFERENCE

1. Fischel, Jack, Butchart, Stanley P., Robinson, Glenn H., and Tremant, Robert A.: Flight Studies of Problems Pertinent to Low-Speed Operation of Jet Transports. NASA MEMO 3-1-59H, 1959.

## TEST AIRPLANE

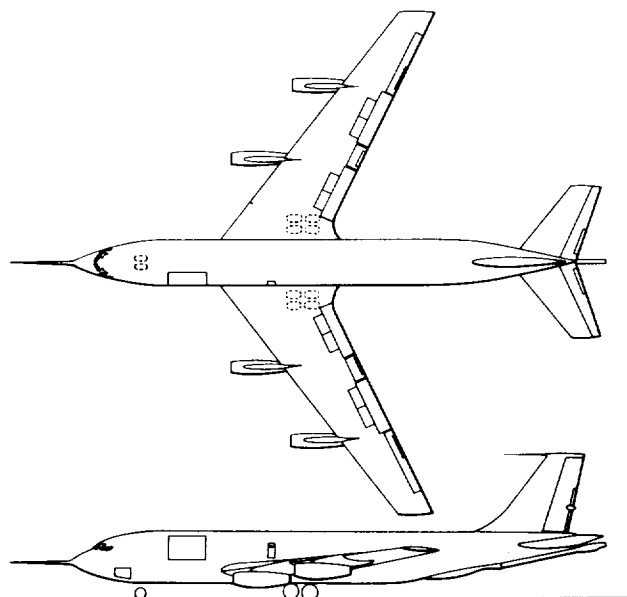


Figure 1

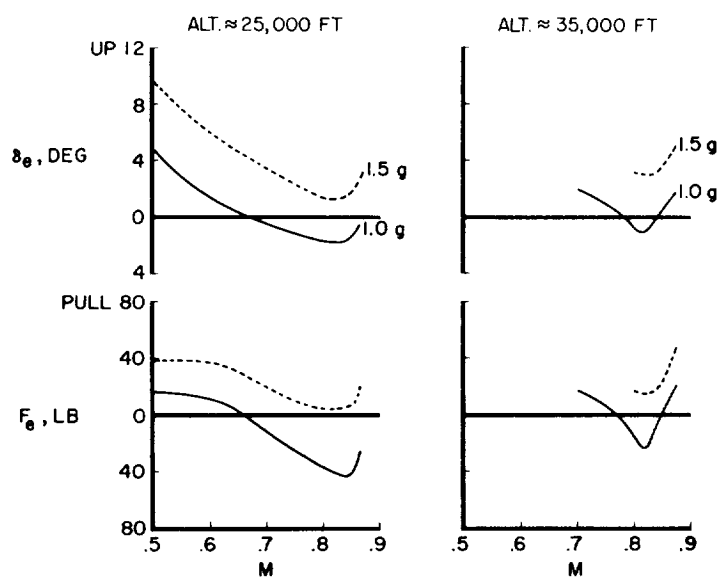
LONGITUDINAL TRIM CHARACTERISTICS  
POWER ON

Figure 2

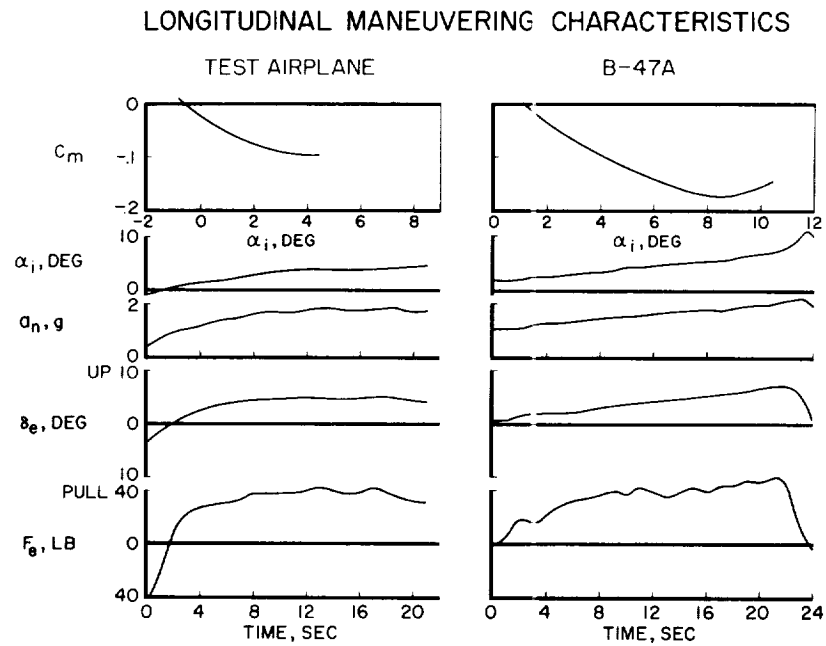


Figure 3

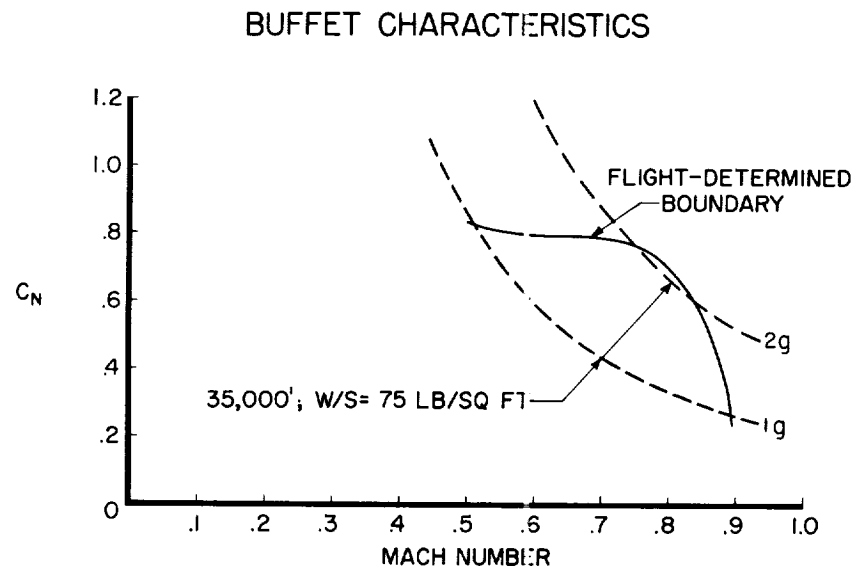


Figure 4



## DYNAMIC LATERAL-DIRECTIONAL CHARACTERISTICS

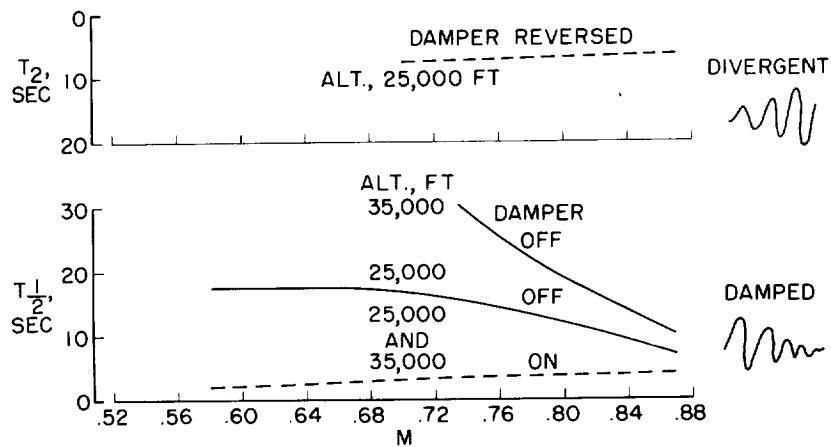


Figure 5

## RUDDER-FIXED ROLL CAPABILITY

ALT. = 35,000 FT

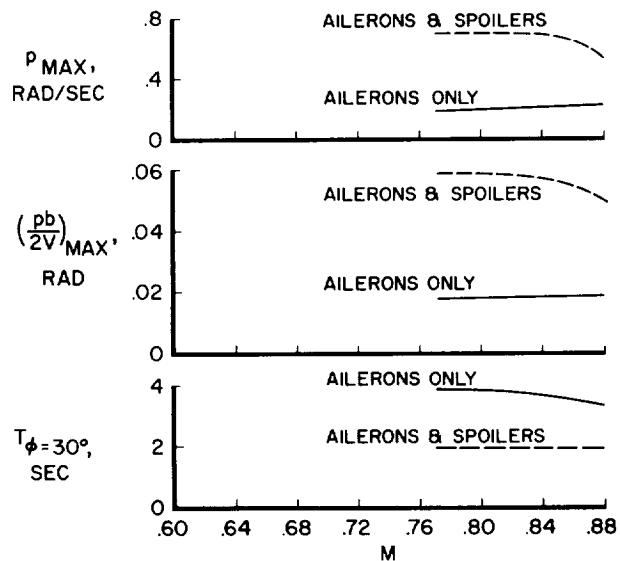


Figure 6

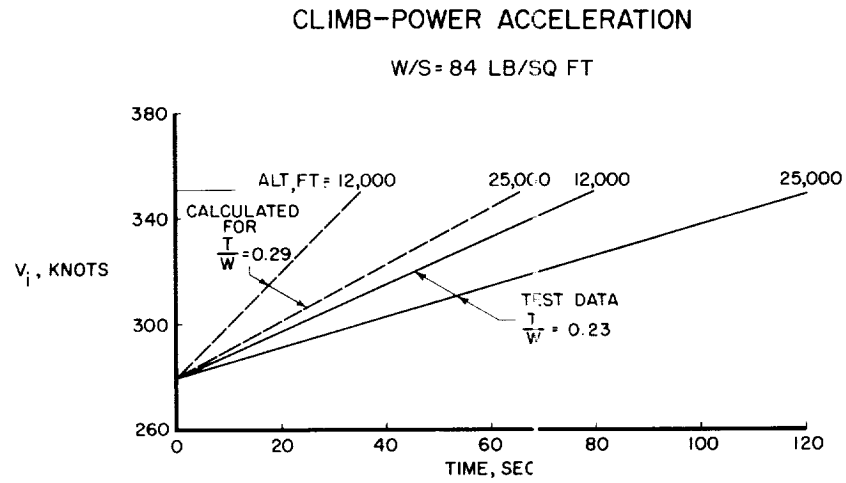


Figure 7

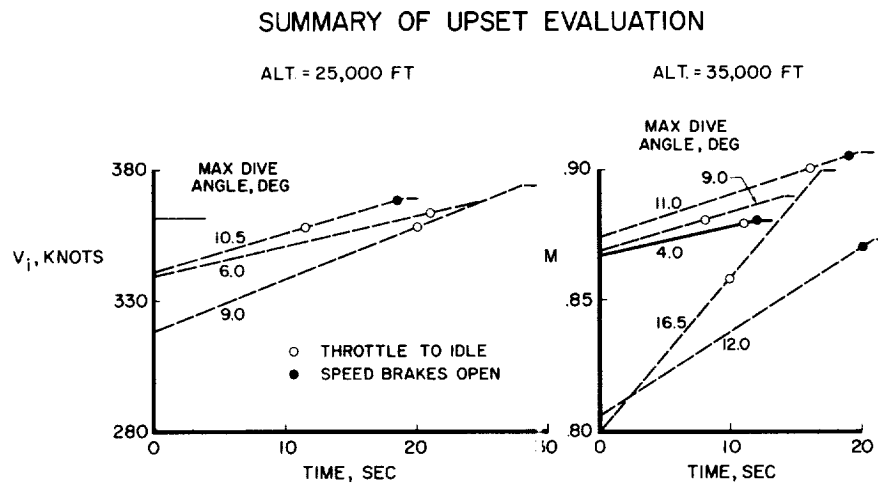


Figure 8

## SLOW-DOWN CHARACTERISTICS

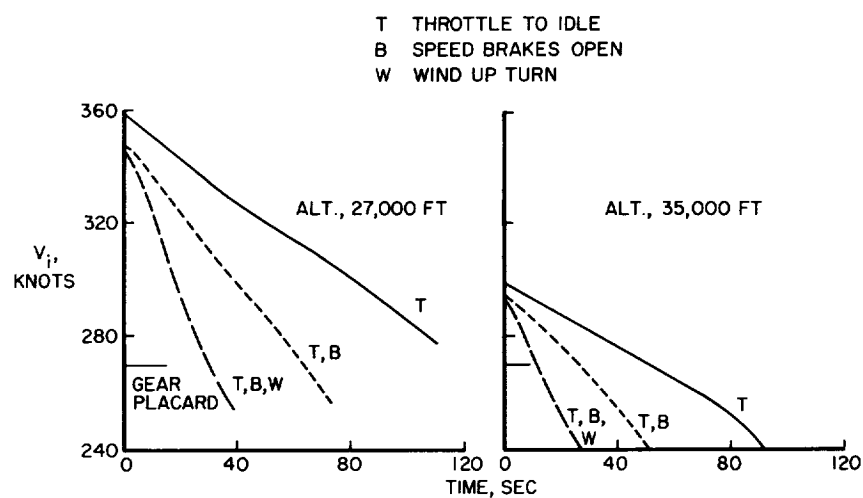


Figure 9

## DESCENT CHARACTERISTICS

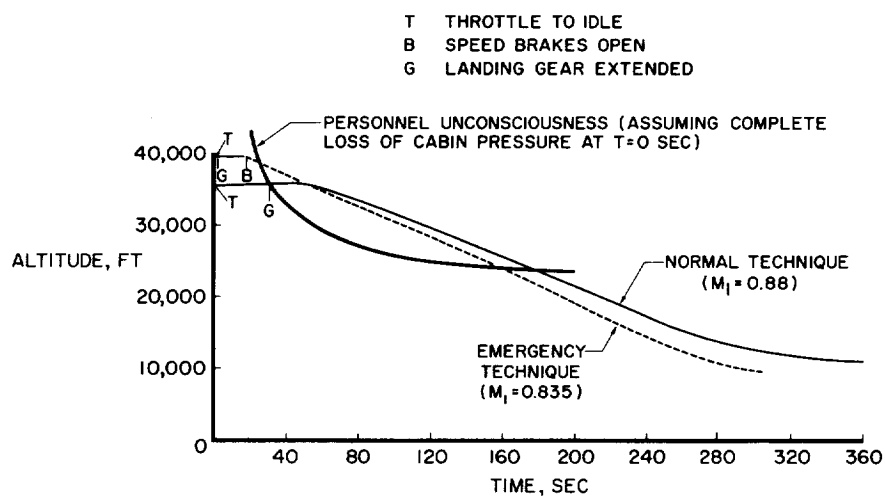


Figure 10



<p>NASA MEMO 3-2-59H National Aeronautics and Space Administration. FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED OPERATION OF JET TRANSPORTS. Stanley P. Butchart, Jack Fischel, Robert A. Tremant, and Glenn H. Robinson. April 1959. 17p. diags. (NASA MEMORANDUM 3-2-59H)</p> <p>Some of the specific areas investigated include: (1) an overall evaluation of longitudinal stability and control characteristics at transonic speeds, with an assessment of pitch-up characteristics, (2) the effect of buffeting on airplane operational speeds and maneuvering, (3) the desirable lateral-directional damping characteristics, (4) the desirable lateral-control characteristics, (5) an assessment of overspeed and speed-spread requirements, including the upset maneuver, and (6) an assessment of techniques and airplane characteristics for rapid descent and slow-down. The results presented include pilot's evaluation of the various problem areas and specific</p> <p>(over)</p> <p>Copies obtainable from NASA, Washington</p>	<ol style="list-style-type: none"> <li>1. Mach Number Effects - Complete Wings (1.2.2.6)</li> <li>2. Stability, Static (1.8.1.1)</li> <li>3. Stability, Dynamic (1.8.1.2)</li> <li>4. Control (1.8.2)</li> <li>5. Flying Qualities (1.8.5)</li> <li>I. Butchart, Stanley P.</li> <li>II. Fischel, Jack</li> <li>III. Tremant, Robert A.</li> <li>IV. Robinson, Glenn H.</li> <li>V. NASA MEMO 3-2-59H</li> </ol>	<p>NASA MEMO 3-2-59H National Aeronautics and Space Administration. FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED OPERATION OF JET TRANSPORTS. Stanley P. Butchart, Jack Fischel, Robert A. Tremant, and Glenn H. Robinson. April 1959. 17p. diags. (NASA MEMORANDUM 3-2-59H)</p> <p>Some of the specific areas investigated include: (1) an overall evaluation of longitudinal stability and control characteristics at transonic speeds, with an assessment of pitch-up characteristics, (2) the effect of buffeting on airplane operational speeds and maneuvering, (3) the desirable lateral-directional damping characteristics, (4) the desirable lateral-control characteristics, (5) an assessment of overspeed and speed-spread requirements, including the upset maneuver, and (6) an assessment of techniques and airplane characteristics for rapid descent and slow-down. The results presented include pilot's evaluation of the various problem areas and specific</p> <p>(over)</p> <p>Copies obtainable from NASA, Washington</p>	<ol style="list-style-type: none"> <li>1. Mach Number Effects - Complete Wings (1.2.2.6)</li> <li>2. Stability, Static (1.8.1.1)</li> <li>3. Stability, Dynamic (1.8.1.2)</li> <li>4. Control (1.8.2)</li> <li>5. Flying Qualities (1.8.5)</li> <li>I. Butchart, Stanley P.</li> <li>II. Fischel, Jack</li> <li>III. Tremant, Robert A.</li> <li>IV. Robinson, Glenn H.</li> <li>V. NASA MEMO 3-2-59H</li> </ol>	<p>NASA MEMO 3-2-59H National Aeronautics and Space Administration. FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED OPERATION OF JET TRANSPORTS. Stanley P. Butchart, Jack Fischel, Robert A. Tremant, and Glenn H. Robinson. April 1959. 17p. diags. (NASA MEMORANDUM 3-2-59H)</p> <p>Some of the specific areas investigated include: (1) an overall evaluation of longitudinal stability and control characteristics at transonic speeds, with an assessment of pitch-up characteristics, (2) the effect of buffeting on airplane operational speeds and maneuvering, (3) the desirable lateral-directional damping characteristics, (4) the desirable lateral-control characteristics, (5) an assessment of overspeed and speed-spread requirements, including the upset maneuver, and (6) an assessment of techniques and airplane characteristics for rapid descent and slow-down. The results presented include pilot's evaluation of the various problem areas and specific</p> <p>(over)</p> <p>Copies obtainable from NASA, Washington</p>	<ol style="list-style-type: none"> <li>1. Mach Number Effects - Complete Wings (1.2.2.6)</li> <li>2. Stability, Static (1.8.1.1)</li> <li>3. Stability, Dynamic (1.8.1.2)</li> <li>4. Control (1.8.2)</li> <li>5. Flying Qualities (1.8.5)</li> <li>I. Butchart, Stanley P.</li> <li>II. Fischel, Jack</li> <li>III. Tremant, Robert A.</li> <li>IV. Robinson, Glenn H.</li> <li>V. NASA MEMO 3-2-59H</li> </ol>	<p>NASA MEMO 3-2-59H National Aeronautics and Space Administration. FLIGHT STUDIES OF PROBLEMS PERTINENT TO HIGH-SPEED OPERATION OF JET TRANSPORTS. Stanley P. Butchart, Jack Fischel, Robert A. Tremant, and Glenn H. Robinson. April 1959. 17p. diags. (NASA MEMORANDUM 3-2-59H)</p> <p>Some of the specific areas investigated include: (1) an overall evaluation of longitudinal stability and control characteristics at transonic speeds, with an assessment of pitch-up characteristics, (2) the effect of buffeting on airplane operational speeds and maneuvering, (3) the desirable lateral-directional damping characteristics, (4) the desirable lateral-control characteristics, (5) an assessment of overspeed and speed-spread requirements, including the upset maneuver, and (6) an assessment of techniques and airplane characteristics for rapid descent and slow-down. The results presented include pilot's evaluation of the various problem areas and specific</p> <p>(over)</p> <p>Copies obtainable from NASA, Washington</p>	<ol style="list-style-type: none"> <li>1. Mach Number Effects - Complete Wings (1.2.2.6)</li> <li>2. Stability, Static (1.8.1.1)</li> <li>3. Stability, Dynamic (1.8.1.2)</li> <li>4. Control (1.8.2)</li> <li>5. Flying Qualities (1.8.5)</li> <li>I. Butchart, Stanley P.</li> <li>II. Fischel, Jack</li> <li>III. Tremant, Robert A.</li> <li>IV. Robinson, Glenn H.</li> <li>V. NASA MEMO 3-2-59H</li> </ol>
---	--	---	--	---	--	---	--

NASA MEMO 3-2-59H

recommendations for possible improvement of jet-transport operations in the cruising speed range.

NASA MEMO 3-2-59H

recommendations for possible improvement of jet-transport operations in the cruising speed range.

Copies obtainable from NASA, Washington

NASA

Copies obtainable from NASA, Washington

NASA

NASA MEMO 3-2-59H

recommendations for possible improvement of jet-transport operations in the cruising speed range.

NASA MEMO 3-2-59H

recommendations for possible improvement of jet-transport operations in the cruising speed range.

Copies obtainable from NASA, Washington

NASA

Copies obtainable from NASA, Washington

NASA